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A study of China–India cooperation in renewable energy field ☆

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Abstract

This paper analyses the present situation of renewables international cooperation in China and India and the reasons, basis and conditions of China-India cooperation for renewable energy and explores China-India cooperation strategies for renewable energy. This study indicates that (1) the two countries have made a lot of progress in the international cooperation of renewable energy, but China-India cooperation for renewable energy is still in its primary stage; (2) there are not only the common benefits but also the solid basis and good conditions for China-India cooperation in the field of renewable energy; (3) there is need to explore and design the cooperation strategies for renewable energy of China and India in order to strengthen renewables cooperation between two countries.

Keywords: Cooperation; China; India; Renewable energy

Contents

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1. Introduction

China and India are two most populous developing countries in the world. Both the countries are undertaking reforms and sharing the common goal of prosperity, peace and good environmental quality for citizens of all countries and future generations. Development of sustainable energy is core component of pursuing this goal. To meet increasing domestic requirements for energy of a sustainable level, however, China and India have to face the twin challenges of meeting the growing energy needs and reducing the share of fossil-fuel-based energy. One way to overcome the twin challenges for both countries is to focus on renewable energy as a promising energy source [1]. As "Our Common Future" indicated, "A safe and sustainable energy path is crucial to sustainable development; we have not yet found it... Renewable energy sources should form the foundation of the global energy structure during the 21st Century" [2].

In China and India the importance of increasing use of renewable energy sources in the transition to a sustainable energy base was recognised and a significant thrust was given to the development of variety of renewable energy technologies. Moreover, China and India have complementary and mutually supporting abilities to contribute to accelerate the development for renewable energy. Each country has successful strategies and methods in developing renewable energy [3]. Each country has experience in specific technological fields. Each country has advantages in implementing the next stage in technological development. Each country has achieved a lot in international cooperation for renewable energy. In this scenario, China–India cooperation in renewable energy field has become imperative and helpful due to collaboration with regard to technology, policies and

institutions can help to overcome the problems of renewable energy development, meet the challenges and achieve their common goal.

Both China and India realise the vital need for international cooperation, inter-linkage of China and India programmes with bilateral and multilateral programmes and initiatives in popularisatising renewable energy. In fact, in the present context, (1) it has become more relevant for achieving the national as well as the global objectives of sustainable energy development [4] and (2) the actions of sustainable energy development taken within its national boundaries have impacts far from its borders.

In December 2000, a Chinese delegation visited India. During this visit, the proposal for entering into a memorandum of understanding (MoU) for enhanced cooperation in renewable energy was discussed and based on the discussions a modified draft MoU was prepared [5].

On 23 June 2003, the Ministry of Water Resources, the government of the People's Republic of China and the Ministry of Non-conventional Energy Sources, the government of the Republic of India, signed the MoU for enhanced cooperation in the field of renewable energy.

This MoU seeks to establish cooperation in the field of small hydropower, wind power and other areas of renewable energy through joint research and development activities, exchange of technical expertise and information networking. The ultimate objective is to commercialise the result of such cooperation, create business opportunities and facilitate sustainable market development in an environmentally responsible manner. Areas of cooperation will be defined by mutual consent in accordance with the interest of experience of the scientific, technological and industrial institutions and personnel of the two countries and the facilities available. The MoU provides for exchange of scientific and technological problems, formulation and implementation of joint research and development and demonstration projects on application of renewable energy technologies for augmenting energy availability in a cost-effective manner, training of personnel and setting up of technical demonstration projects in areas of renewable energy [6].

The problem is how to put the MoU into force and strengthen China–India cooperation in the field of renewable energy in practise. Up to now some main issues of China–India cooperation in renewable energy field have not been adequately explored and/or sought after. Therefore, it is necessary to study the reason, basis, conditions and strategies of the cooperation between the two countries.

The remaining sections of paper are presented as follows: Section 2 analyses the present situation of international cooperation for renewable energy in China and India. Section 3 deals with the main reason, basis and conditions of the cooperation between two countries. Section 4 explores the strategies of China–India cooperation in renewable energy field. Final section remarks conclusions.

2. Present situation of renewables international cooperation in China and India

Both China and India realise the vital need for international cooperation, inter-linkage of their programmes with bilateral and multilateral programmes and initiatives in popularisatising renewable energy. For a long time, the two countries have taken lots of measures to strengthen international cooperation for renewable energy and have made much progress in this aspect. Both countries' international cooperation activities in renewable energy sector are primarily focused on sharing experiences and expertise with

other countries, promoting co-operation in scientific research in technologies of interest, mobilising financial resources for programmes and promoting human resource development in the field of renewable energy.

2.1. Present situation of international cooperation for renewable energy in China

As a developing country, China has been confronted with the long-standing dilemma between energy supply increase and environmental protection. In order to overcome the dilemma, the Chinese government has made significant efforts to develop renewable energy and consistently regarded intensifying international cooperation in the field of renewable energy as a cornerstone policy. Strengthening international cooperation for renewable energy is an important content stressed in a series of China's action plans for promoting renewable energy development. These action plans include "new and renewable energy development plan for 1995–2010", "new and renewable energy industrial development planning outline for 2000–2015" and "The tenth five-year plan for the development of the new energy and renewable energy industry". In "new and renewable energy development plan for 1995–2010", the importance, principle and way of international cooperation for renewable energy was stated as follows:

> It is imperative to make full use of the present favorable chance to carry out international exchanges and cooperation while continuing the principle of self-independent development with introducing of state-of-the-art process and equipment discriminately in order to develop the new and renewable energy technology from a higher level. Further enlarge the field of cooperation, and strengthen the contact and cooperation with international organizations. Advocate bilateral and multilateral cooperation in research and production. Intensify exchanges of personnel, technology and information. Adopt feasible steps to attract international organizations, social groups, entrepreneurs and individuals to invest or open joint ventures or run solely foreign-owned enterprises in the field of the new and renewable energy.

Under the above guidelines, China has been firmly promoting international cooperation to seek feasible ways of developing renewable energy and the utilisation of renewable energy. Through this activity, China has various channels with foreign countries and international institutions for the exchange of technical and policy information and development of joint programs, and disseminates the obtained information to the interested parties at home and abroad.

International activities of China have been pushed forward two sides. One is the bilateral cooperation with foreign countries, and the other is the multilateral co-operation with international organizations. The selected main projects below demonstrate China's progress in the international cooperation for renewable energy for many years.

2.1.1. Multilateral cooperation

Cooperation with UNDP/GEF: "capacity building for the rapid commercialization of renewable energy." This project began in March 1999. Designed to promote renewable energy development and a commercial renewable energy industry, the project provides training, workshops, demonstration installations, business development, policy

facilitation, equipment standards, company and product certification, and overall industry support. The project focuses on five sectors: (1) village-scale power for household electrification and rural industry using hybrid wind and solar PV systems with battery storage and diesel backup generators, (2) biogas from industrial and agricultural organic waste effluents, (3) solar hot water heating for buildings, (4) wind power for grid-based power generation, and (5) bagasse cogeneration for grid-based power generation. The project has been financed with US$8.8 million from the GEF, US$3.0 million from the Australian AusAid Program, US$2.5 million from the Netherlands government, and US$11.5 million from Chinese sources of co-financing [7].

Cooperation with GEF/ WB: ''China renewable energy development project''. Implementation period of this project is 5 yr, from 2001 to 2006. The project aims to use state-of-the-art and cost-effective wind and PV technologies to supply electricity in an environmentally sustainable way and to provide modern energy to dispersed rural households and institutions. The contents of the project mainly includes: (1) installing 190 MW of windfarms at Huitingxile, Inner Mongolia (100 MW), Zhangbei, Hebei Province (50 MW), Pingtan, Fujian Province (20 MW), Nanhui, Shanghai Municipality (6 MW) and Chongming Island, Shanghai Municipality (14 MW), mainly to promote the technology in locations with high public visibility; (2) assisting PV system companies to market, sell, and maintain 10 MWp of PV systems, an estimated 300–400,000 systems, in Qinghai, Gansu, Inner Mongolia, Xinjiang, Tibet, western Sichuan and adjacent areas; and (3) providing financial assistance to industries producing wind or PV equipment, to accelerate technology innovation aimed at reducing costs while providing high quality products and performance. The project has been financed with US$100 million from the World Bank loan and US$35 million from GEF grant [8].

Cooperation with Asian Development Bank (*ADB*): (1) ADB funding prefeasibilty studies and assessments in biogas and wind at about US$1 million; (2) on 20 December 2000, ADB approved a US$58 million loan to support the development of three grid-connected wind farms, one each in the Xinjiang Uygur Autonomous Region and the provinces of Heilongjiang and Liaoning with a combined capacity of 78 MW, under the wind power development project. The project of the wind farms involves cofinancing from Global Environment Facility for the construction of the wind farms and for barrier removal and institutional strengthening to promote the development of additional wind farms; (3) on 23 October 2002, ADB approved a US$33.1 million loan to promote the generation of clean renewable energy from agricultural biomass wastes in the provinces of Henan, Hubei, Jiangxi and Shanxi of China. The total cost of the project is US$77.3 million equivalent, of which US$6.4 million will come from the Global Environment Facility, US$14.2 million from beneficiaries and US$23.6 million from local governments. ADB's share comes from its ordinary capital resources [9].

Cooperation with UNF: ''solar water heating project''. The project, jointly sponsored by the State Trade and Economic Commission (SETC) and the United Nations Foundation, focuses on the integration of solar water heating systems into buildings. It aims at boosting China's solar water heating technology. According to the scheme, the SETC, together with the Ministry of Construction, will organise demonstration projects for the integration system in three Chinese cities within 3 yr, devise relevant evaluation standards and train some designers and installers for the projects. Implementation period of the project is 3 yr, from 2001–2004. The funding of the project is 11.4 million US$, of which 1.8 is from UNF and 9.8 is from Chinese finance [10].

2.1.2. Bilateral cooperation

Cooperation with US: (1) under the Chinese State Science and Technology Commission—DOE 1995 protocol on energy efficiency and renewable energy and its six annexes, US funding for China's programme in solar, biomass, wind, hybrid systems, geothermal, electric vehicles and so on at about US$2 million; (2) as part of the energy and environment cooperation initiative, part of a now US$100 million loan programme at the US Export–Import Bank has been earmarked for US companies interested in developing renewable energy projects in China; (3)US DOE–Chinese Ministry of Agriculture: biomass cooperation under way since 1996; (4) Energy Research Institute–National Renewable Energy Laboratory collaboration: under the renewable energy protocol [11].

Cooperation with Italy: "the solar village project". This project is one of the pilot projects, in which the Italian Ministry for the Environment and Territory launched a cooperation programme with the China State Environmental Protection Administration (SEPA), the Chinese Academy of Social Sciences of Beijing (CASS) and the Ministry of Science and Technology (MOST) in 2000. The Sino–Italian joint venture between the China National Photovoltaic Centre and Eurosolare (ENI Group) has established in Ningbo the first Chinese factory to produce polycrystalline silicon wafers for solar energy with productive capacity of 2 MW/yr. Following the joint-venture, the solar village project was developed, under the agreement with MOST, aiming at the promotion and dissemination of solar energy in rural areas where there are no conventional power grid extensions. The project carried out in the Inner Mongolia will meet the challenge of poverty relief, sustainable economic development and environmental protection. The possibility of incorporating the project as a pilot case under the CDM's rules of the Kyoto Protocol will be also investigated [12].

Cooperation with Germany: "wind power project in China's Hubei". The project is in cooperation with the German government under China's clean development mechanism (CDM), created as part of the Kyoto Protocol in 1997. The wind power project in Hubei is the first one of its kind being prepared under the framework of the CDM. With financial support from the German Ministry of Economic Cooperation and Development, a 3 yr study of wind conditions in Lichuan, which found the region has great potential for wind power projects, has resulted in plans for the construction of a medium-sized 20 million W wind station. The station is subsequently to be expanded by an additional 50 million W if warranted [13].

Cooperation with Britain: "clean energy research project". China's top research body, the Chinese Academy of Sciences (CAS), and the world's second largest oil group, British Petroleum, announced they would work together to study clean energy. According to an agreement reached by the two parties, the CAS–BP China Center will work together in clean energy research over the next decade. The British company agreed to contribute 10 million US dollars to the centre, which is the fifth BP research centre worldwide. The centre's headquarters is to be set up at the CAS Institute of Chemical Physics in Dalian, Liaoning Province. Researchers from other CAS institutes as well as from Qinghua University and the Chinese University of Science and Technology will also take part in the research programme [14].

Cooperation with Holland: "CERUPT: Inner Mongolia Huitengxile wind power project". The Holland government initiated the CERUPT in November 2001 to promote the effect of Kotyo protocol. The target is to purchase 3MCERs, in the fields of renewable energy, biomass, energy efficiency and clean fuel. This project is expected to install the

wind power facility with capacity of 23.1 MW in Inner Mongolia Huitengxile of China. The project's duration is from 2004 to 2013 (the installation of facility will be in year 2003, but still need the permission from the State Development Planning Commission (SDPC)). The funding of the project totals 174 M Chinese RMB Yuan, in which 80% will be from Holland loan. The project is expected to sell Holland government 0.675MCERs through CERUPT (3.6 M Euro) [15].

Cooperation with Kenya: The Chinese government donated US$160,000 to implement a pilot solar energy program for Kenya in order to help solve the power shortage in rural areas of the East African country. The solar system, which about 80 Kenyan households are expected to benefit from, can power four lights for the villagers' evening life, and a television for the education and entertainment of each household [16].

In addition to the cooperation mentioned above, China also is receiving bilateral assistance in renewable energy technologies from Denmark, Spain and Japan. Australia and Spain are also co-donors to the UNDP project [17].

2.2. Present situation of international cooperation for renewable energy in India

In India the Ministry of Non-conventional Energy Sources has taken initiatives for accelerating international co-operation activities in the field of renewable energy. These initiatives have been taken in close co-operation with the State Renewable Energy Development Agencies, research and development institutions, industrial institutions, Indian Renewable Energy Development Agency and other central ministries [18]. India has achieved a lot in international operation, greatly enhanced corporate development, technology and management through importing large amounts of funds, technology, equipment and managerial experience, and made huge progress in renewable energy development and applications.

The selected major projects below reflect Indian achievements of international cooperation in the filed of renewable energy.

Cooperation with UNDP/GEF: (1) "optimizing development of small hydel resources in hilly areas". UNDP/GEF provided a financial assistance of US$7.5 million grant and US$7.14 million co-financing for this project. The project formulates technical and economic guidelines and furthers adoption of advanced technologies for small hydro resources in India's hilly region, which should reduce carbon emissions and mitigate deforestation. An integral part of government programme to expand prevalence of non-conventional energy sources, the project uses a more cost-effective design than those of present India plants in this field. The project is an integral part of the MNES mini–micro hydel programme for creating an additional total capacity of 256 MW, of which about 70 MW would be in the hilly regions [19]; (2) UNDP/GEF assisted project on "development of high rate biomethanation processes as a means of reducing green house gases emission". The project commenced in September 1994 for the duration of 5 yr. UNDP/GEF provided a financial assistance of US$5.5 million. The UNDP/GEF funds are utilised mainly for acquisition of technologies, consultancy services, engagement of experts, organisation of training programmes, study tours, workshops/seminars and creation of awareness, etc., and part of the cost of installation of demonstration sub-projects [20]; (3) "carbon emission reduction through biomass energy for rural India". This project began in May 2001. The total cost of the project is US$8.6 million, with GEF and India Canada Environment Facility (ICEF) contributing US$4.01 million and US$2.49

million, respectively. The major objectives of the project are to demonstrate the technical and financial viability of bioenergy technologies, build up the capacity and appropriate mechanisms for implementation, management and monitoring of the project and to develop financial, institutional and market strategies to overcome the identified barriers for large-scale replication of the bioenergy package for decentralised applications. The project is proposed to be implemented in a cluster of 24 villages in Tumkur district of Karnataka [21]; (4) ''fuel cell bus (FCB) development in India''. This project began in May 2001. The project proposes a 5 yr demonstration programme of operating and testing eight FCBs for public transport in Delhi. The major objective is to introduce this zero emission and highly efficient bus technology in India for reducing local air pollution and global GHG emissions. It will assist the Indian transport sector to gain capability of manufacturing, operating, and servicing FCBs under local conditions. It will also help create an initial volume demand and provide useful feedback of operating experience for the FCB developers/manufacturers to further improve the bus design and reduce the bus cost. The project has been financed with US$6.280 millions from GEF grant and US$5.841 millions from co-financing [22]; (5) on 15 October 2002, the GEF Council approved a US$39.15 million project, ''removal of barriers in biomass power generation in India'', to promote the use of environmentally friendly biomass energy in India. The project will focus on removing the technical, regulatory and institutional barriers to using biomass energy, which is fuelled by renewable plant material such as rice husks and straw, bagasse, sugarcane tops and wastes from other agricultural products. The project is funded by a US$5.65 million GEF grant. A major share of the project's US$33.50 million in cofinancing was leveraged by the Indian government from the country's private sector [23].

Cooperation with UNFCCC: ''Indian hybrid energy project—world renewable spiritual trust'', an activities implemented jointly (AIJ) project under UNFCCC. The project involves installation of ten renewable energy-based hybrid systems in different parts of India. The project also envisages transfer of the state-of-the-art single-phase ''solar mains diesel hybrid'' (SMD) series technology to India. The International Green House Partnership Office of the government of Australia is providing an assistance of US$235,246 for the project. It has been estimated that as a result of the project, emission of 630 tonne of CO_2 per year would be avoided [24].

Cooperation with World Bank/GEF: (1) World Bank assisted ''India renewable resources development project'' (IRRDP) and ''second renewable energy project'' with a total cost of US$160 million and US$135 million, respectively; (2) a project proposal entitled ''enhancing access through off-grid electrification in the state of Rajasthan'' was recommended for GEF PDF-B assistance of US$331,198/-. The PDF activity envisages development of a plan for electrification of 1065 villages through off-grid/mini-grid renewable electricity service models in Rajasthan with the core objective of transforming the off-grid/mini grid developments to a sustainable business model. It is estimated that at the end of the PDF activity, a project with US$55 million as investment component and about US$2.5 million as technical assistance component would be developed; (3) World Bank fielded energy-environment missions during May and December 2001 to develop strategic climate change partnership (CCP) with India in the areas of policy support for renewable energy and energy-efficient options, market expansion/creation for renewable energy in rural electrification and introduction of high-efficiency water pumps in the agricultural sector. The World Bank has proposed the partnership under the GEF programmatic approach and has estimated that the above programme would be

implemented over a period of 8–12 yr with GEF resource of approximately US$175 million and co-financing from the World Bank, IFC, etc. in the range of US$2–3 billion [25].

Cooperation with ADB: (1) the ADB assisted "India renewable energy development project" with a total loan assistance of US$100 million; (2) "promotion of the renewable energy, energy efficiency and green house gas abatement" (PREGA). The ADB provided technical assistance for this project. The main objective of the project is to promote investments in renewable energy and energy efficiency technologies and to generate a pipeline of such investment projects for consideration for financing through commercial, multilateral and bilateral sources and from GEF and CDM. The other objectives include developing capabilities of national policy makers and technical experts, supportive policy, regulatory and institutional reforms and removing energy pricing distortions [26].

Cooperation with Germany: (1) KfW of Germany had given a line of credit of DM 120 million to Indian Renewable Energy Development Agency (IREDA) for providing loans to commercial projects in wind energy, baggase-based co-generation and solar photovoltaic sectors. (2) Discussions were held for German assistance to the integrated solar combined cycle power project at Mathania, Jodhpur, Rajasthan [27].

Cooperation with Myanmar: "Indian assistance for village electrification in Myanmar". Within the ambit of India–Myanmar S&T co-operation, MNES has provided financial assistance and hardware for the electrification of Yanmyoaung village in Myanmar through solar photovoltaics. Central Electronics Limited has executed the project and it has been commissioned in February 2003 [28].

3. Reason, basis and conditions of China–India cooperation for renewable energy

The two countries have made the above progress in international cooperation of renewable energy, but China–India cooperation for renewable energy is still in its primary stage. To move China–India cooperation to greater heights, it is an urgent task at the moment to study the reason, base and conditions of the further China–India cooperation in the field of renewable energy and have an in-depth study of the common benefit tendency of renewable energy cooperation between the countries.

3.1. Foremost reason of the cooperation: common goal and the same challenges

Why should China–India cooperation for renewable energy be deepened? The foremost reason is that the two countries share the common goal and face the same challenges.

As two most populous developing countries in the world, China and India share goals in eradicating poverty and improving living standards. In 2002 the population of China totals 1.28 billion, accounting for about 21% of the world population. China's population is projected to rise to 1.38 billion in 2010, and 1.51 billion by 2020. India is second in the world population, after China. India's population reached 1.05 billion and accounts for 16% of the world population in 2002. It is projected to increase to 1.20 and 1.42 billion, respectively, in 2010 and 2020 [29]. During the last two or three decades, China and India have made substantial progress in most spheres of development. The two countries have been among the fastest growing in the world. Social indicators have improved. Literacy and enrolments have risen. Morbidity and mortality have declined. Gender gap declined. Poverty rates have fallen steadily. The countries have attained food sufficiency in spite of

their growing population. They have also created a large base of skilled scientific and technical manpower with a diversified industrial base. However, (1) the absolute numbers of people still living below the poverty line of India and China are still very large: they are 260 million and 30 million, respectively, in 2001 [30]; (2) China's and India's human development index (HDI) values 0.721 and 0.59, respectively, classified as medium human development and ranking 104 and 124 out of 175 countries and regions, respectively [31]. On other parameters such as infant mortality, literacy rates, access to amenities, etc. though there has been a distinct improvement over the last couple of decades, the performance of China and India has been less than satisfactory. The challenge before the two countries in terms of improving the basic factors that provide a decent quality of life to their populace is rather onerous.

Energy is core component in eradicating poverty and improving living standards. It contributes directly to meeting both basic needs and more sophisticated human needs. Energy from fossil fuels poses a basic dilemma for sustainable development in that it is necessary for socio-economic growth, however, yet it is associated with environmental degradation, especially with regard to atmospheric pollution. Therefore China and India have to face the twin challenges of meeting the growing energy needs and reducing the share of fossil-fuel-based energy in order to eradicate poverty and improve living standards.

As both the largest energy user and producer, China solved its energy shortage in the 1990s, and has since been able to maintain a stable energy supply and demand balance. However, the heavy dependence on coal, which constitutes 75% of the country's energy consumption mix, has created serious environmental problems. China accounts for about 13% of world carbon emissions, ranking behind the United States [32].

Coal is the major energy resource of India. It accounts for about 58% of the total primary sources of commercial energy. It is expected to maintain its dominant role in economy. Indian coal has a very high ash content and poses a grave threat to India's environment. Coal burning is responsible for many environmental problems such as air pollution, greenhouse gas emissions and land de-gradation due to ash deposition. Oil consumption in India is steadily increasing. The aggregate consumption of petroleum products has risen at an annual rate of 6.1% from 1980/1981 to 1997/1998. At the same time India's production of petroleum products has risen at a rate of 11.3% from 1980/81 to 1997/98. According to the forecast, oil consumption would rise to 396 million tonne and the share of oil would rise to 38% in 2025.

In confronting rising energy demand and environmental constraints, China and India must cooperate to promote the development for renewable energy to limit the severe environmental consequences of future energy consumption while maintaining a sufficient energy supply. The cooperation for renewable energy is beneficial to both countries.

3.2. Solid basis for the cooperation: political trust between China and India

Political trust is a vital basis for closer collaboration between governments, professionals and the private sector.

In June 2003, Chinese Premier Wen Jiabao and visiting Indian Prime Minister Atal Bihari Vajpayee signed a declaration on principles for relations and comprehensive cooperation between China and India. The declaration proposed four principles that China and India would abide by for the promotion of a long-term constructive and

cooperative partnership, and on this basis, the installation of a "qualitatively new relationship."

The four principles are as follows:

> Both sides are committed to developing their long-term constructive and cooperative partnership on the basis of the Five Principles of Peaceful Coexistence, mutual respect and sensitivity for each other's concerns and equality;
>
> As two major developing countries, China and India have a broad mutual interest in the maintenance of peace, stability and prosperity in Asia and the world, and a mutual desire in developing wider and closer cooperation and understanding in regional and international affairs;
>
> The common interests of the two sides outweigh their differences. The two countries are not a threat to each other. Neither side shall use or threaten to use force against the other; and
>
> Both sides agree to qualitatively enhancing the bilateral relationship at all levels and in all areas while addressing differences through peaceful means in a fair, reasonable and mutually acceptable manner. The differences should not be allowed to affect the overall development of bilateral relations.

Moreover, the Indian government has for the first time recognised, in an explicit way, Tibet Autonomous Region as part of China's territory. The Tibet issue has long been the most important and sensitive issue in China–Indian relations. This demonstrates that the declaration has resolved the problem of the lack of political trust between the two countries from a legal perspective. It will promote mutual trust and the long-term development of bilateral relations. It provides solid basis for cooperation in the economic and cultural fields, renewable energy field included and for the further development of the bilateral relationship as a whole.

In addition, the two sides also signed an MoU for enhanced cooperation in the field of renewable energy and the other eight documents on cooperation in economy, law and justice, science and technology, and culture. This shows that both the governments of China and India realise the vital need for two countries' cooperation in the field of renewable energy. The MoU outlined the cooperation of the two countries in the field of renewable energy. According to the MoU, China and India seek to establish cooperation in the field of small hydropower, wind power and other areas of renewable energy through joint research and development activities, exchange of technical expertise and information networking. The ultimate objective is to commercialise the result of such cooperation, create business opportunities and facilitate sustainable market development in an environmentally responsible manner. Areas of cooperation will be defined by mutual consent in accordance with the interest of experience of the scientific, technological and industrial institutions and personnel of the two countries and the facilities available. The MoU provides for exchange of scientific and technological problems, formulation and implementation of joint research and development and demonstration projects on application of renewable energy technologies for augmenting energy availability in a cost-effective manner, training of personnel and setting up of technical demonstration projects in areas of renewable energy. The MoU was the formal diplomatic document. So the MoU provides not only an action guide but also a strong political underpinning for China–India cooperation in the field of renewable energy.

3.3. Main conditions for renewables cooperation

There are several main conditions for China–India cooperation in the field of renewable energy. These conditions mainly include:

3.3.1. Resources and market potential of renewable energy

Both China and India not only have abundant potential of renewables resources (see Table 1), but also set ambitions but not yet sufficient goals to share of renewable energy on the overall energy consumption. China wants to increase the share to 4.2% by 2015 [33] and India strives for 10% of renewable energy in the year 2012 [34].

However, renewable energy in both China and India still represent a niche market share. In China wind power, solar energy, hydropower and other renewable energy resources accounted for only 1.8% of the total annual commercial energy consumption in 2000 [35]. In 1998 Indian renewable energy (including hydro) was only 2.5% of the total commercial primary energy [36]. Therefore, both China and India have huge potential of renewables markets. The renewables resources and market potential of China and India create condition to deepen the bilateral renewables cooperation.

3.3.2. Similar and different strategies and methods of renewables development

Both China and India have stressed the importance of renewable energy in meeting their development needs. Significant efforts of both countries have gone into the design, development, field demonstration and large-scale use of a number of renewable energy products and systems.

Both countries have set their strategic objectives for renewables development by outlining and listing these in their national five year plans during the different periods.

Goals and thrust areas of the development for rural renewables in China are similar to those in India due to the similar background, resource conditions and infrastructure. The goals are to raise the conversion efficiency, reduce the production cost and increase the proportion of renewable energy in the energy structure. The thrust areas include wind, biomass, small hydro, solar, marsh gas and geothermal.

The Indian strategic objectives for the development of renewable energy have the identified direction and approach including enhancing the diversity and security of energy supplies, promoting private-sector participation and competitiveness. In addition, they have included the participation of more women in the renewable energy programme for their employment and empowerment relating to the use of cooking energy in all

Table 1
Renewable energy potential in China and India

	China	India
Wind energy	252 (GM)	45,000 (MW)
Small hydro power	450 (GM)	15,000 (MW)
Biomass energy	600 (million TCE)	19,500 (MW)
Solar energy	100 (GM)	35,000 (MW)

Sources: Ministry of Non-conventional Energy Sources and http://www.iges.or.jp/en/cp/output_all/workshop/ClimateAsia/china/presentation/cpd-c-12.pdf.

households and are providing cost effective energy for water pumping, irrigation, drinking and rural electrification and all round rural development through integrated rural energy programme. Furthermore, there are detailed action plans at state or local level in the strategy objectives of India. For example, India has clear guidance from the government and a comparatively prefect framework of the legislation and fiscal polices for renewable energy development. However, the Chinese strategic objectives lack a clear direction and approach and the detailed action plans at state or local level.

A number of strategy measures have been taken by both countries to accelerate the development of renewables.

China and India use similar economic incentive options including government subsidies, tax incentives, price policies and the low interest loans and interest subsidies for publicly leveraged market-driven deployment of renewable energy technologies. However, there are some differences between these two countries in the economic incentive options:

(1) In China only the government, both central government and local governments provide various types of fiscal incentives for the development of renewable energy, but does not offer renewables production incentives. This results in a lack of domestic manufacturing capability in China. In India, however, MNES provides economic incentives for the development of renewables besides the central government and states. Unlike China, moreover, India has renewable energy production incentives. As a result, a substantial manufacturing base has been created in a variety of RETs, placing India in a position, not only to export technologies, but also to offer technical expertise to other countries. By the late 1990s, e.g., dozens of domestic wind turbine manufacturers had emerged. Many of these manufacturers feature the latest high-technology turbine designs. Although wind turbine blades are still largely imported, domestic production of blades has begun and export of blades and synchronous generators to Europe is taking place.
(2) In China, direct government subsidies to customers of renewable energy and applications are a common policy option that is used to accelerate renewables market. Although direct government subsidies for renewables are effective in accelerating the renewable energy market, there are several issues relating to government subsidies, one being the source and availability of funds. Government will have to make a large capital investment in order to significantly stimulate the development of renewable energy markets. Its limited and long-term availability is uncertain because the funds for subsidy comes from the government's general revenue. The strategy and objective of government subsidies is another issue. Who should receive the subsidies, what should be the level of subsidies, the developmental goal of subsidies and who will decide the levels? These are important issues that need to be addressed.

In India, the Ministry of Non-conventional Energy Sources (MNEs) announced a new strategy and action plan to replace subsidy-driven programmes with commercialization in 1992. Financial incentives were trimmed and fiscal incentives, such as concessional tax rates, along with soft loans, were introduced to encourage enterprise. Several renewable energy technologies (RETs) such as wind, solar thermal, solar photovoltaics (SPV) and small hydro (SHP) are now promoted on a commercial scale.

It is the intention of both Chinese and the Indian governments to support renewable energy R&D. Both countries have made substantial investment in the renewable energy

R&D fields and have established dedicated renewable energy research institutes. However, there are substantial differences between these two countries in renewable energy R&D. For example, India has a comparatively prefect framework for the renewable energy R&D. It consists of R&D strategy, industrial R&D policy, an R&D Advisory Committee and R&D thrust areas. MNES, industry and the consortium consisting of industry, academic institutions, research laboratory and R&D institution participates and supports these activities by sharing the cost of projects in India. Furthermore, many states also actively participate and support R&D activities. In China almost all renewable energy R&D activities are carried out by the central government. Local government and industry rarely participate in renewable energy R&D.

Strategy management for renewable energy development differs considerably between China and India.

The Indian government, through it various committees such as Fuel Policy Committee (1974), Working Group on Energy Policy (1979), Advisory Board on Energy (1985), Energy Demand Screening Group (1986), etc. has formulated programmes aimed at rural renewable energy and implemented through Ministry of Non-conventional Energy Sources to achieve the goal of strategy management for renewable energy development.

The Indian strategy management model, which Ministry of Non-conventional Energy Sources is responsible for all matters regarding the strategy management for non-conventional/renewable energy development, produces a positive effect for setting strategic objectives, policy making, planning, promotion and co-ordination of various demonstration and commercial programmes, designing and implementing fiscal and financial incentives, creation of industrial capacity, promotion of R&D and technology development, intellectual property protection, human resource development and international relations. This has increased the efficiency of strategy management for renewable energy development and accelerated the renewables development in India.

In China, however, tasks of the strategy management for renewable energy development have been divided into various departments, such as Ministry of Agriculture (MOA), Ministry of Science and Technology (MOST), Small Turbine Association, State Development Planning Commission, State Economic and Trade Commission and State Power Corporation (SPC). The Chinese strategy management framework brings out a number of problems. They include overlapping functions, multi-management, decentralised funds, duplication constructions and divided policies from various sources, etc. This has weakened the ability of national intervention in the renewable energy development and hindered the development of renewable energy in China to some extent.

The above similar and different strategies and methods of renewables development in China and India provide important condition for countries' cooperation in the field of renewable energy. It is beneficial for both countries to exchange and share their experiences and successful strategies through their cooperation.

3.3.3. Technology advantages of renewable energy

Although only a fraction of the aggregate potential in renewables in both countries has been utilised so far, India and China have both made significant progress in the development of renewable energy. China and India have various technologies and advantages in renewable energy field, so they can be mutually complementary. And China and India can learn from each other's strengths to offset their weaknesses. This also is

necessary condition for strengthening China–India cooperation in the field of renewable energy.

For example, China has the largest biogas and improved stove programmes with some 90% of worldwide installations in the world. China has good experience in developing small hydropower. There are currently more than 43,000 small hydropower plants in China with a combined installed capacity of more than 28 million kW [37]. China is a top-ranked country in the production and sales of solar water heaters [38]. India has the largest decentralised solar energy programme, the second largest biogas and improved stove programmes and the fifth largest wind power programme in the world, representing more than two-thirds of the total wind power capacity in developing countries. A substantial manufacturing base has been created in a variety of RETs, placing India in a position to not only export technologies but also to offer their technical expertise to other countries [39].

4. Strategies for renewables cooperation between China and India

From the analysis of the Section 3, it is found that there are not only the common benefits but also the hard foundation and good conditions for China–India cooperation in the field of renewable energy. The problem is how to make full use of these conditions to promote China–India renewables cooperation and achieve the common benefits of China and India. It is significant for both China and India to explore and design their cooperation strategies for renewable energy.

Taking into account the diversity that exists in the situations of two countries, strategies for strengthening China–India cooperation in renewable energy field are addressed below. These strategies are presented for the purpose of facilitating further discussions on frameworks for renewables cooperation between China and India; the list is intended to be indicative, rather than exhaustive, of the strategies that could be considered. Many of the strategies have far-reaching political, financial and organisational implications.

4.1. Creating an academies committee

In order to promote the collaboration between China and India, a primary task is to explore and identify the opportunities and priorities for the cooperation of research, development, demonstration and development of renewable energy. Although governments of China and India emphasise renewables cooperation of both sides, up to now the opportunities and priority for the cooperation in this aspect have not been adequately examined and identified in detail. Therefore, first and foremost strategy that could be considered for enhancing China–India cooperation in renewable energy is to create an academies committee, which consists of equal numbers of researchers from each side alternately in China and India, to explore and identify the opportunities and priorities for renewables cooperation between countries.

4.2. Establishing the forum for a dialogues involving high-level officials, key industry players, consumers of renewable energy and other relevant stakeholders

The need for a regular dialogue on the policies, product and consumption for renewable energy in China and India has been noted. A renewable energy forum that China and India

jointly sponsor could be a strategy to bring together heads of government, leaders from the renewable energy industry, main consumers of renewable energy, commercial banks, academic and research institutions, etc. By bringing together key leaders, such an initiative might provide a useful forum through dialogue and engagement to expedite action in key areas that could contribute to greater development for renewable energy and explore bilateral beneficial opportunities for investment in renewable energy.

4.3. Sharing manpower and know-how

Human resources development should be an important element in China–India cooperation strategies for renewable energy. On the one hand, the efforts should be mounted to fully utilise the best research and training centres of renewable energy in the two countries to train young experts. To facilitate this goal, governments of China and India co-sponsor a massive programme of scholarships to enable students to pursue graduate and postgraduate education in these institutions. On the other hand, the human resources needed for policy-making, planning, project implementation, management and operation of energy systems could also be shared. Effective sharing, however, necessitates development of a new mechanism. A renewable energy centre for two countries could be considered to set up supported by the governments.

4.4. Establishing an information network of renewables technologies expertise, manufacturing capabilities and commercial availability of renewables products

Linking a number of professional institutions in China and India into a network focusing on renewable energy information including renewables technologies expertise, manufacturing capabilities and commercial availability of renewables products could facilitate greater interaction between them, which might enable countries to learn from each other and thereby optimise their collective effort and avoid duplication where possible. This strategy provides a forum for China and India collaborations in the field of renewable energy, and could also help in establishing standards and best practices, thereby contributing to greater diffusion of renewable energy technologies. The exchange of information regarding research and development on renewable energy can be arranged through seminar, workshop, study visit, etc.

4.5. Establishing cooperation programmes for promoting public–private partnerships for technology transfer

Renewables technologies developed in China and India, especially ones in rural areas of two countries, although often modelled on those in industrialised countries, have more chance of being adopted by the two countries due to certain similar characteristics between both countries. Strategies that could be considered for promoting the transfer of renewable energy technologies include initiatives in the form of China–India partnership programmes involving public and private entities. Such a participatory approach with cost-sharing arrangements can be a strategy for transfer and adaptation of such renewable energy technologies: solar, wind, biomass and hydro.

4.6. Sharing renewable energy

Although much renewable energy production is highly local in nature, there are also opportunities for sharing renewable energy resources in China and India. The geopolitics of two countries will always have a bearing on national decision-making, but at the operational level such sharing can be developed largely on a commercial basis through market mechanisms.

As we know, there are the abundant renewable energy resources in neighbouring area of China and India. It is possible for China and India to share renewable energy resources if the two countries take advantage of these resources to jointly develop the renewable power and create an interconnection of power grids across political boundaries of two countries through the cooperation of two sides, and most electricity produced from renewable sources are fed into the interconnection of power grids and marketed by electric utilities.

4.7. Establishing a regular review of the progress of renewable energy cooperation

The governments of China and India should establish a regular review of the progress of renewable energy collaboration in order to better meet strategic objectives of the two countries' cooperation for renewable energy. In China and India a lot of renewable energy programme are being performed by different government agencies, international agencies and research institutes.

The periodic renews of renewable energy cooperation— including solar, wind, biomass and hydro—and frequent information exchange among institutions would result in better coordination of international programme.

5. Conclusion

To overcome the problems of renewable energy development, meet the challenges and achieve their common goal, China and India have emphasise international cooperation in renewable energy field and made much progress in international cooperation of renewable energy. Although the renewables cooperation between two countries is still in its primary stage due to some reason, there are not only the common benefits but also the hard foundation and good conditions for China–India cooperation in the field of renewable energy. Therefore, China and India should design sounds strategies based on the diversity that exists in the situations of two countries to promote the renewables cooperation between two countries and achieve their common benefits. First and foremost strategy that should be considered for enhancing China–India cooperation in renewable energy is to create an academies committee, which consists of equal numbers of researchers from each side alternately in China and India, to explore and identify the opportunities and priorities for renewables cooperation between countries.

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